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Collaborative Studies of Polar Cap Ionospheric Dynamics

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13. ABSTRACT *(Maximum 200 words)*

This contract was awarded to the Space Physics Research Laboratory of The University of Michigan to continue data acquisition and analysis efforts using a set of optical instruments housed in a trailer on the pier at Thule Air Base in Greenland. The primary experimental program remotely measured neutral winds and temperatures at ~250 km altitude. Published results from these investigations are included in this report. In addition, the following secondary programs were initiated during the term of this contract: a) the measurement of neutral winds at ~95 km altitude; b) the measurement of neutral temperatures at mesopause altitudes; c) the acquisition of all sky images of airglow/auroral emissions. The station operated in an automatic data acquisition mode during the months September to April during the period covered by this contract. This document describes the instrumentation at the site and displays the results of the analysis performed on the data acquired by the instrumentation.

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INTRODUCTION

The primary scientific goal for the Thule optical facility was to acquire measurements of thermospheric winds and temperatures during the dark observing seasons covered by this report (the months September to April; the seasons 1986/7, 1987/8, and 1988/9). Secondary goals were 1) to initiate a lower thermospheric wind and temperature measurement capability with the Fabry Perot interferometer; 2) to continue the measurement program of the AFGL spectrophotometer; 3) to test an all sky camera system; and 4) to support various NSF, AFGL, and CEDAR sponsored measurement campaigns.

The data acquired by the Fabry Perot interferometer has been used to extend the thermospheric database coverage for Thule from the initial December, 1985, period to the conclusion of the 1988/9 observing season. The initial observations have been used in concert with the NCAR Thermospheric General Circulation Model to improve the understanding of the thermodynamics of the polar cap ionosphere [*Meriwether et al.*, 1988; *McCormac et al.*, 1988]. The airglow facility at Thule is the high latitude anchor of a latitudinal chain of Fabry Perot interferometer stations devoted to observing the OI (6300 Å) emission feature. Thus, the F region measurements obtained at Thule provide valuable data in a global effort at improving our understanding of the dynamic state of the upper atmosphere.

The Ebert Fastie spectrophotometer has been used to observe emissions from various nightglow features including NI (5200 Å), OI (5577 Å), OI (6300 Å), Balmer H_a (6563 Å), OII (7320/30 Å), and the OH (8-3) vibrational band. In addition, several of these features are enhanced in aurora, and thus the spectrophotometer serves as an auroral monitor aiding the interpretation of lower thermospheric temperature measurements. Interpretation of the rotational development of the hydroxyl band permits the investigation of temperature, gravity wave, and tidal motions at the mesopause. In addition, lower atmosphere scattering from air base Hg vapor lamps was monitored and served as an indicator of sky transparency conditions.

An additional trailer was obtained and placed next to the old trailer. An all sky camera was housed under a dome in the new trailer during the 1988/9 observing season. The sky was observed through several filters including OI (5577 Å), OI (6300 Å), and OII (7320/30 Å) for the purpose of coordinating measurements of sun aligned arcs with both the Fabry Perot interferometer and the Ebert Fastie spectrophotometer. The current layout of the Thule facility is shown in Figure 1. The original trailer with its two domes is in the background, the old phase shack / power supply shack is on the right, and the new trailer with its single dome is in the foreground on the left.

The optical facility has been in operation during most of the winter CEDAR campaigns during the report period. Data has been acquired for several LTCS and HLPS campaigns as well as for GITCAD/GISMOS and other global efforts.

This final report will summarize optical facility activity in Thule, present results from the various experiments, and describe work that is currently in progress. Included are reprints of two papers published in the Journal of Geophysical Research, and several abstracts of papers presented or to be presented at AGU meetings. Two graduate student theses are based on data acquired at Thule and a report on the progress of their research is included.

EXPERIMENTAL ASPECTS OF THE THULE FACILITY

Three instruments are installed under separate domes at Thule Air Base, Greenland. The primary instrument is the Fabry Perot interferometer, and this is supplemented by an Ebert Fastie spectrophotometer and an all sky camera system. The Fabry Perot interferometer has been observing the OI (6300 Å) emission line profile since the start of operation of the Thule ground site. The scan sequence includes a measurement in the zenith followed by observations in the four cardinal directions at elevation angles of 45 degrees. The typical integration period is a few minutes for a 100 Rayleigh signal and is determined primarily by waiting for the signal minus background count to exceed a predetermined minimum. The statistical uncertainties for neutral winds and temperatures are on the order of 15 m/sec and 50 K respectively. In addition to monitoring the sky signal, a Ne lamp emission at 6330 Å is also observed. This is accomplished by moving the mirror system to a position that looks into the box containing the calibration source. By calculating a pseudo wind from the Ne emission, any drifts in the stability of the instrument may be taken into account. Typically, in any 24 hour period, the instrument remains stable to within 25 m/sec. Finally, the dark count rate is also monitored and removed from the sky signal. Additional information regarding setup and routine operation of this instrument may be found in *Meriwether et al.* [1987].

During the period covered by this report, several changes were made to the Fabry Perot experiment. The free spectral range coverage was increased in September, 1987, from approximately 45% to nearly 100% at 6300 Å, accomplished by changing the focal lengths of the collimating and condensing lenses. This permitted an excellent determination of the background sky signal that is required in the data analysis. In an effort to increase the count rate, a new filter for 6300 Å with a higher transmission and lower sideband passage was inserted in the filter wheel, also in September, 1987. The combination of these two changes noticeably reduced the integration period for acquiring an OI (6300 Å) fringe as compared to the previous season for an equal signal level. As a by product of increasing the free spectral range coverage, the pressure level within the etalon chamber no longer required fine tuning during a night's worth of data coverage. This reduced markedly the scatter in the wind measurements for any 24 hour period. Figure 2 shows the results for the set of OI (6300 Å) measurements acquired during the period local noon on day 347, 1988, to local noon the following day. The horizontal wind components may be combined to produce a horizontal vector wind and displayed in a polar dial coordinate system either as a geographic latitude / local solar time plot (Figure 3) or as a geomagnetic latitude / corrected geomagnetic local time plot (Figure 4).

The most important change in the operation of the Fabry Perot interferometer was the addition of a lower thermosphere capability. This was accomplished as a response to the desire from the CEDAR aeronomical community to have measurements of the line shape profile of the OI (5577 Å) emission during the September, 1987, LTCS campaign. The filter used has a bandwidth of 3 Å centered slightly above the green line peak wavelength. Tilting the filter fine tunes the Fabry Perot's response to the sky emission. The filter remains in use in Thule along with the OI (6300 Å) filter necessitating a bi-filter scanning sequence. At each pointing direction, first a green line fringe is acquired and then a red line fringe before moving the mirror system to a new direction. With the new OI (6300 Å) filter mentioned above, a full scan including the lower thermosphere measurements as well as the dark and Ne experiments requires on the average 20 minutes. Figure 5 shows the results from a run with the green line filter. Note that during this run, the upper atmosphere was still partially sunlit.

The 0.5m Ebert Fastie spectrophotometer has been operating at the Thule site during the period of this report. Prior to the summer of 1989, the instrument was interfaced to the same data acquisition computer as the Fabry Perot interferometer and used the same data control crate. The instrument is pointed at the zenith which, in Thule, is approximately the geomagnetic zenith direction. The detector is a GaAs photomultiplier tube which has a relatively high quantum efficiency in the first order wavelength coverage of the spectrophotometer - ~3800 to ~7600 Å. The instrument routinely monitors several nightglow emissions as well as the scattering from low altitude clouds or fog from base lighting. During attended operation, wavelength and intensity calibrations are routinely performed. A set of spectral lamps permits wavelength calibration while a calibrated intensity source allows intensity calibration. This source has been characterized many times during its lifetime, most recently in September, 1987. The source has a peak response near 6300 Å of 7 R/Å and may be used to intensity calibrate the spectrophotometer over its full range of sensitivity. In addition, while an operator is present, the intensity calibration is transferred to the Fabry Perot interferometer by pointing the latter instrument at the zenith. Knowledge of the filter transmission functions plus the results of the cross calibration experiments allows a reasonable estimate as to the true brightness of the nightglow viewed by the Fabry Perot interferometer. Figures 6a to 6d portray the variation of several emissions during the course of one night of observation. The raw data are plotted in a three dimensional contour display: encoder step (from which wavelength is determined), UT, and count rate as the contour. The first three panels show the variation of the scattered Hg base light, the variation of the OI (5577 Å) emission, and the OI (6300 Å) emission. The final panel displays the OH (8-3) band development with the R branches at ~5590, the Q(1) line at ~5650, the Q(2) line at ~5660, the $P_2(2)$ line at ~5690, the $P_1(2)$ line at ~5710, the $P_2(3)$ line at ~5730, the $P_1(3)$ line at ~5750, the $P_2(4)$ line at ~5790, the $P_1(4)$ line at ~5810, the $P_2(5)$ line at ~5840, the $P_1(5)$ line at ~5860, the $P_2(6)$ line at ~5920 and the $P_1(6)$ line at ~5940.

In an effort to increase the efficiency of the the spectrophotometer experiment, the instrument was interfaced with an IBM AT clone computer during the 1989 down season. This was accomplished at SPRL by two students funded by the REU program. The rationale for this major change was twofold: one, to make the experiments in Thule truly independent; and two, to upgrade the computer control system to current state of the art levels. The upgrade was motivated by the successes that were made during the startup efforts in September, 1987, and November, 1988. Both the Fabry Perot interferometer and the Ebert Fastie spectrophotometer experiments performed so well that the single data acquisition computer became overloaded with data prior to a site visit and, as a result, shut down for lack of disk space. Rather than increasing disk space on the old PDP 11/23 computer, weaning the spectrophotometer experiment away from this computer and interfacing with its own system with an optical disk drive data storage unit was the preferred solution. This new arrangement was tested in Ann Arbor in September, 1989, and was shipped and installed at Thule Air Base in November, 1989.

During the fall of 1987, an additional trailer was placed next to the original Wells Fargo trailer. The new trailer had one hole cut into the ceiling with a clear Plexiglass dome placed over it. During late January and early February, 1988, Dr. Meriwether utilized this new dome for a stratospheric NO_2 measurement experiment. In November, 1988, Dr. McCormac placed an all sky camera system under this dome. The detection system for this experiment makes use of a bare CCD placed at the focal plane of an all sky camera lens system. The filter wheel with its complement of filters was placed above the input optics. Since it was decided at the very start that there would not be any image intensification, the CCD must be kept as cold as possible to reduce the dark count inherent within the device. This is accomplished in several ways. First of all, the trailer housing this experiment is kept

at ambient temperature which is near -30° C during the winter months. Secondly, the Peltier cooling system that was supplied by the vendor was supplemented with a thermoelectric cooling system. Dark counts were observed to be as low as 5 counts per 300 seconds. The current version of the experiment is capable of imaging sub-visual auroral arcs and patches at 5577 and 6300 Å. The images are recorded on video tape for playback and analysis in Michigan. Figures 7a and 7b display images acquired by this experiment. Vectors indicating the strength of the neutral wind at the appropriate wavelength are also included.

RESULTS

The Thule facility was brought on line during fall 1986 by Drs. Killeen and McCormac. It was again visited by Dr. McCormac in January, 1987, in support of a GITCAD campaign. The site was next visited by Drs. Meriwether and Niciejewski in February, 1987, and two more times by Dr. Niciejewski in March and April, 1987, the latter for a shut down operation. The 1987/8 observing season was initiated by visits in September, 1987, by Drs. Killeen, McCormac, and Niciejewski, and was manned from September to November by Mr. J. Thayer. During that period, the Thule facility supported the September '87 LTCS campaign. Dr. Meriwether visited the site in January, 1988, to support a NOAA NO_2 campaign. The site was visited by Dr. Niciejewski in February, 1988, during the February '88 HLPS campaign. Shut down operations for the 1987/8 season were performed by Dr. Meriwether in April, 1988. The 1988/9 season began with visits by Dr. McCormac and Mr. Thayer in November, 1988. The facility was then serviced in December, 1988, by Mr. Thayer and Mr. Turnbull during the December '88 HLPS campaign. The site was next visited by Dr. Niciejewski in February, 1989, during the CHARM campaign. Shutdown was performed in April, 1989, by Major D. Cannata.

During the periods mentioned above, high quality data were acquired between December, 1986 and April, 1987; September, 1987 and January, 1988; November, 1988 and April, 1989. Cloud cover records have been acquired from the Thule Air Base meteorological station. Much of the Fabry Perot interferometer data and all the cloud cover records have been entered into an "in house" data base at SPRL. Figure 8 shows some results obtained from the data base. The average horizontal neutral wind vectors at F region altitudes for the observing seasons 1987/8 and 1988/9 are displayed on polar dial plots as well as the solar $F_{10.7}$ cm flux.

Two papers resulting from the analysis of Thule Fabry Perot interferometer data are included in this report. These were published in the Journal of Geophysical Research. During the period covered by this report, papers based upon scientific results from the analysis have been presented at the Fall '86 AGU meeting, at the International Symposium on Large-Scale Coupling Between the Ionosphere-Magnetosphere and Thermosphere meeting in Boulder in December, 1986, at the Spring '87 AGU meeting, at the CEDAR symposium in July, 1987, at the Fall '87 AGU meeting, at the Fall '88 AGU meeting, and two papers at the Spring '89 AGU meeting. Three papers using Thule data have been submitted to the Spring '90 AGU meeting in Baltimore, and one to the July, 1990, COSPAR meeting.

The facility at Thule Air Base has been used to train graduate students in the operation and maintenance of ground based optical instrumentation. During the period of this report, the station has been visited by Mr. B. Nardi, Mr. J. Thayer, Mr. G. Wirth, Mr. M. Turnbull, Major D. Cannata, and Ms. E. Trudell. In addition, Mr. D. Barlett and Mr. Y. Won are or have been involved in the data analysis and interpretation of Thule data. Mr. Thayer and Ms. Trudell are completing their graduate degree requirements using data obtained by them from the Thule site, the former using Fabry Perot interferometer data, and the latter using all sky imager data. Both should be completed their respective degree requirements in 1990 (PhD and MsC respectively), and Ms. Trudell will continue studying for her doctorate degree at Michigan by extending her master's research program.

SUMMARY

A computer controlled, automatic airglow facility has been in operation at Thule Air Base during the winter observing periods covered by this report. The instrumentation complement includes a Fabry Perot interferometer monitoring thermospheric emissions from OI (5577 Å) and OI (6300 Å), a spectrophotometer monitoring airglow emissions, and an all sky imaging system monitoring visual to sub-visual auroral arcs and patches. Thermospheric neutral winds and temperatures have been measured routinely since 1985 leading to an initial description of polar cap thermodynamics during the solar minimum and rise to solar maximum phases.

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McCormac, F. G., T. L. Killeen, A. G. Burns, J. W. Meriwether, Jr., R. G. Roble, L. E. Wharton, and N. W. Spencer, Plar cap diurnal temperature variations: observations and modeling, *J. Geophys. Res., 93*, 7466, 1988.

Meriwether, J. W., T. L Killeen, F. G. McCormac, A. G. Burns, and R. G. Roble, Thermospheric winds in the geomagnetic polar cap for solar minimum conditions, *J. Geophys. Res., 93*, 7478, 1988.

Meriwether, J. W., and T. L. Killeen, Final Report for the period 6/10/83 to 9/30/85 - Collaborative studies of polar cap ionospheric dynamics, Air Force Geophysics Laboratory, Air Force Systems Command, 1987, AFGL-TR-87-0012, ADA187888.

FIGURE CAPTIONS

Figure 1. The Thule optical facility consists of two instrumented trailers for scientific research on the left, and a phase shack / power supply shack on the right. The trailer in the foreground on the left houses the all sky camera system, while the trailer in the background contains the Fabry Perot interferometer and Ebert Fastie spectrophotometer.

Figure 2. Summary plot of OI (6300 Å) data for day 347/348, 1988. Time is UT and corresponds to local noon to local noon on the following day. The characters N, W, E, S, Z, and C correspond to measurements acquired in the north, west, east, and south directions at 45° elevation angle, the vertical direction, and the Ne calibration direction. Winds and temperatures are displayed with their statistical uncertainties. Meridional and zonal wind components have been corrected to the horizontal direction. Individual signal intensities are joined together and have not been corrected for van Rhijn effects or absorption / scattering effects. They are also plotted in relative units. The etalon pressure is shown to indicate the stability of the Fabry Perot interferometer which may be judged by the variation in the calibration winds.

Figure 3. Polar dial plot of the meridional and zonal wind components shown in Figure 2 in terms of geographic latitude and local solar time. To obtain the inner vector, the N and E components have been combined, while the outer set of vectors combines the S and W components. The latitude circles are 80° and 70° as one moves radially out from the center. The length of the vector at lower right provides a scale for the wind velocities.

Figure 4. Polar dial plot of the meridional and zonal wind components shown in Figure 2 in terms of geomagnetic latitude and corrected magnetic local time. The vectors are obtained as in Figure 3, but rotated according to the geomagnetic coordinates of Thule Air Base. The latitude circles correspond to 85° and 80° moving out from the center.

Figure 5. Summary plot of OI (5577 Å) data for day 264/265, 1987. Time is UT and corresponds to local noon to local noon on the following day. The characters N, W, E, S, and Z correspond to measurements acquired in the north, west, east, and south directions at 45° elevation angle, and the vertical direction. Winds and temperatures are displayed with their statistical uncertainties. Meridional and zonal wind components have been corrected to the horizontal direction. Individual signal intensities are joined together and have not been corrected for van Rhijn effects or absorption / scattering effects. They are also plotted in relative units. The etalon pressure is shown to indicate the stability of the Fabry Perot interferometer which may be judged by the variation in the calibration winds. In this case, the background signal intensity has not dropped to zero.

Figure 6. Three dimensional contour plots of the intensity variations for various emissions as measured by the Ebert Fastie spectrophotometer on day 264/265, 1987. The data are shown in their raw form. a) Hg (5461 Å); b) OI (5577 Å); c) OI (6300 Å); d) OH (8-3) band.

Figure 7. Images acquired by the bare CCD all sky imaging experiment at Thule. The top two images are obtained through the 6300 Å filter while the bottom two images were made with the 5577 Å filter. Horizontal neutral wind vectors are overlaid for the appropriate emission. a) OI (6300 Å) images at 10:00 and 10:11 UT, and OI (5577 Å) images at 10:06 ant 10:16 UT on 12/12/88; b) OI (6300 Å) images at 10:21 and 10:32 UT, and OI (5577 Å) images at 10:27 and 10:37 UT on 12/12/88.

Figure 8. Average horizontal neutral wind vectors for ~250 km altitude for the 1987/8 and the 1988/9 winter observing seasons at Thule. The $F_{10.7}$ cm solar flux is also shown.

Fig. 1

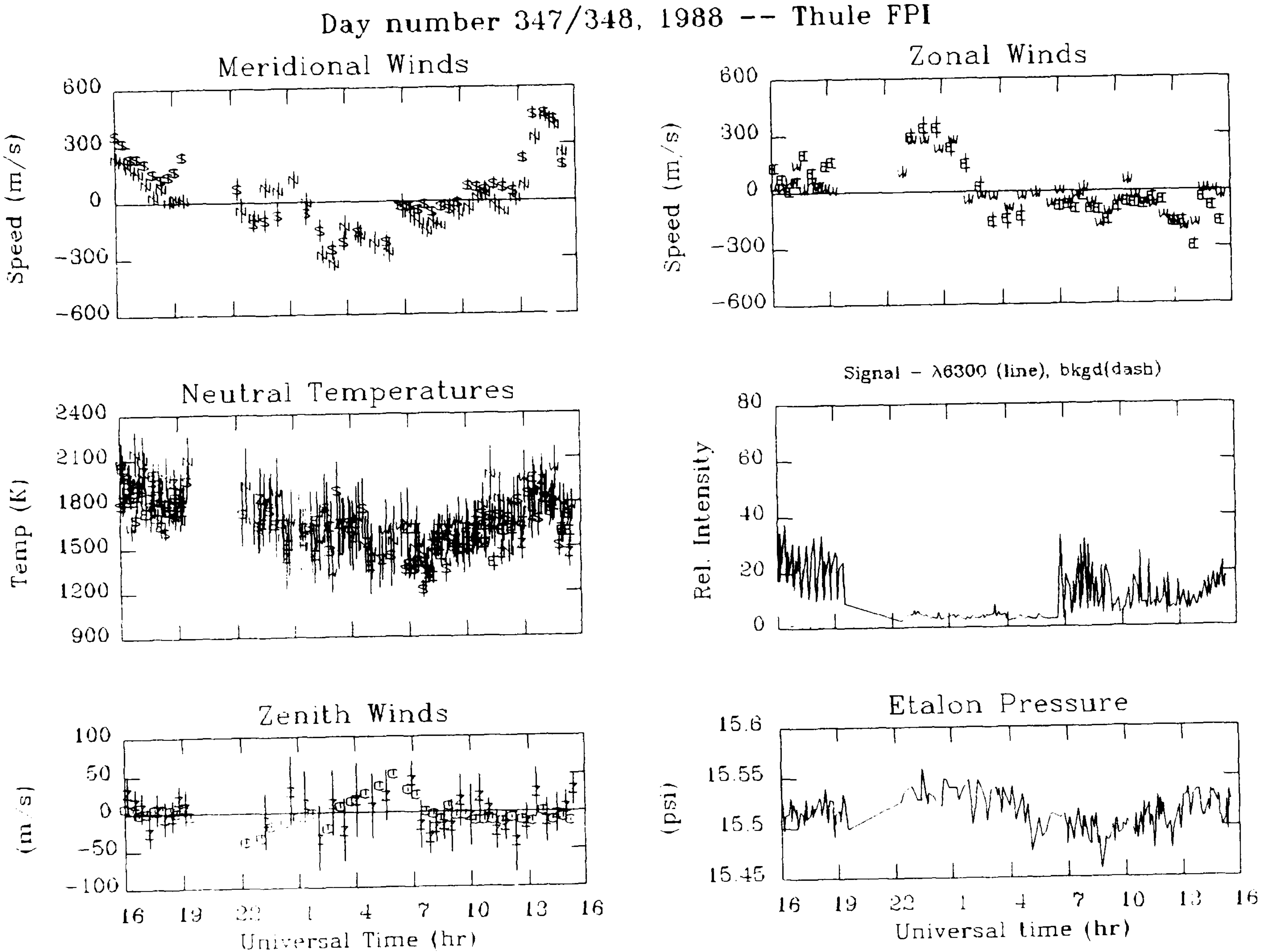

Day number 347/348, 1988 -- Thule FPI
Meridional Winds
Speed (m/s)
600
300
0
-300
-600
Zonal Winds
Speed (m/s)
600
300
0
-300
-600
Neutral Temperatures
Temp (K)
2400
2100
1800
1500
1200
900
Signal - λ6300 (line), bkgd(dash)
Rel. Intensity
80
60
40
20
0
Zenith Winds
(m/s)
100
50
0
-50
-100
16 19 22 1 4 7 10 13 16
Universal Time (hr)
Etalon Pressure
(psi)
15.6
15.55
15.5
15.45
16 19 22 1 4 7 10 13 16
Universal time (hr)

Fig. 2

Day 347/348, 1988 -- Thule FPI

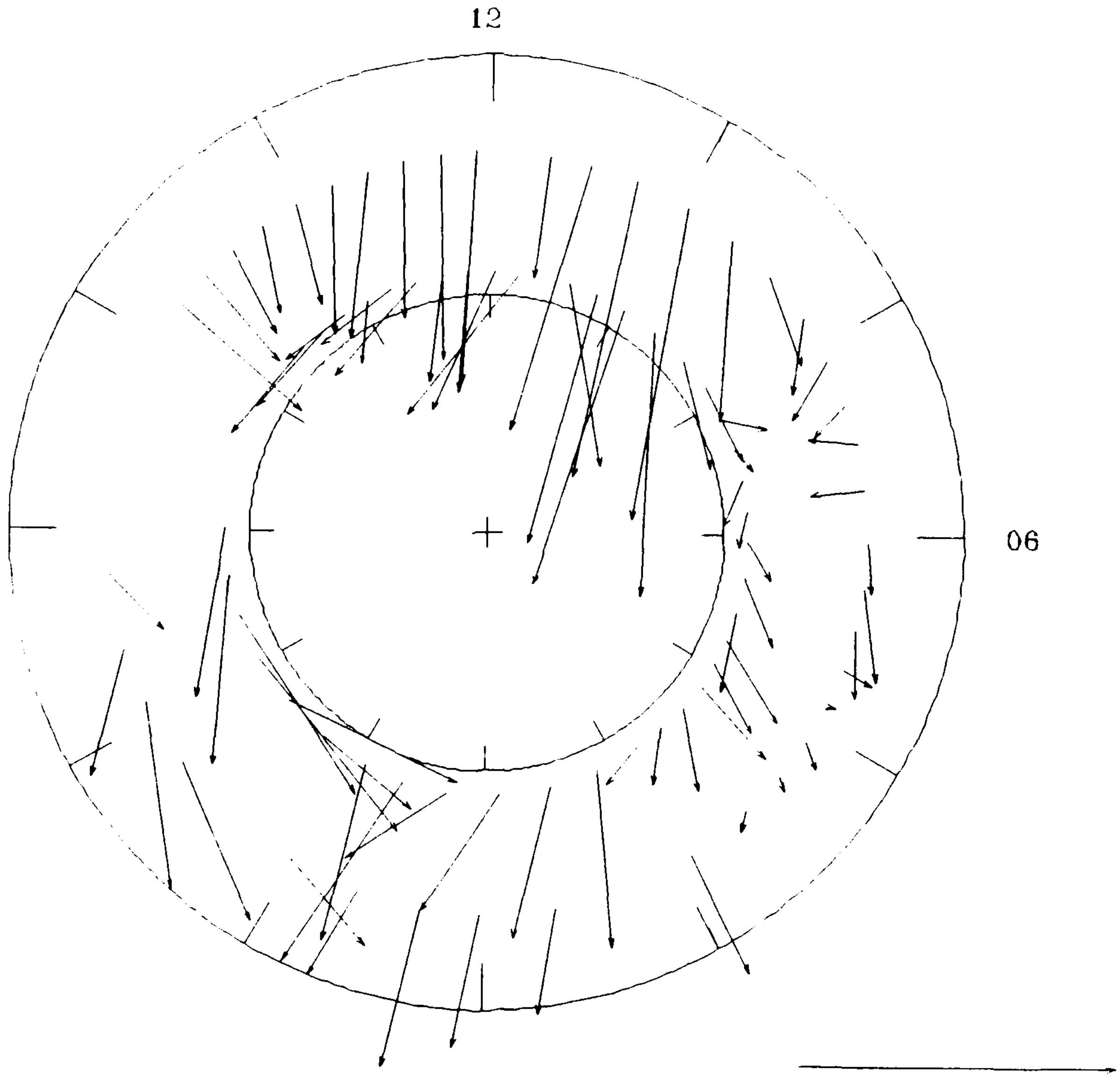


Fig. 3

Day 347/348, 1988 -- Thule FPI

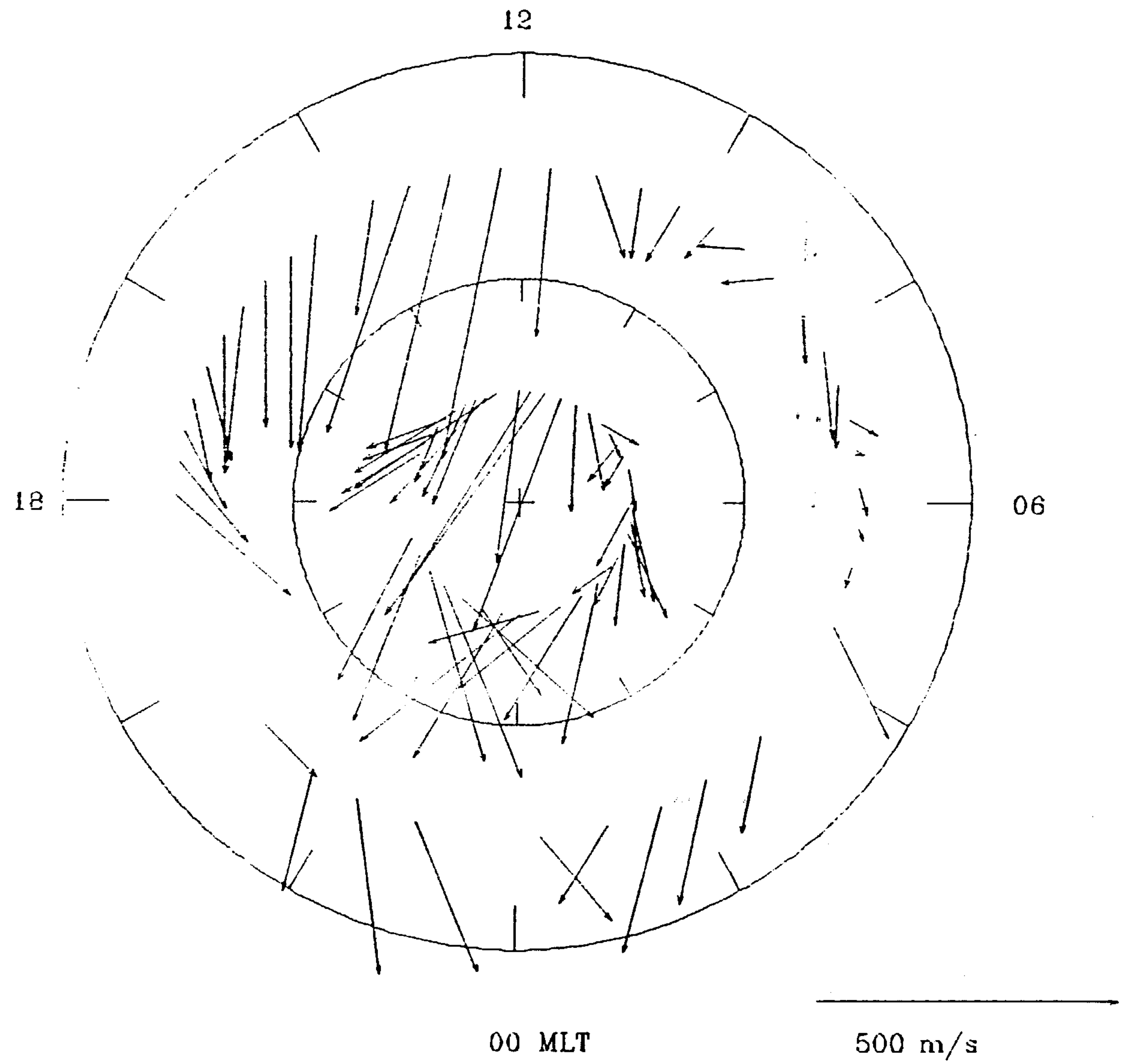


Fig. 4

Day number 264/265, 1987 -- Thule FPI

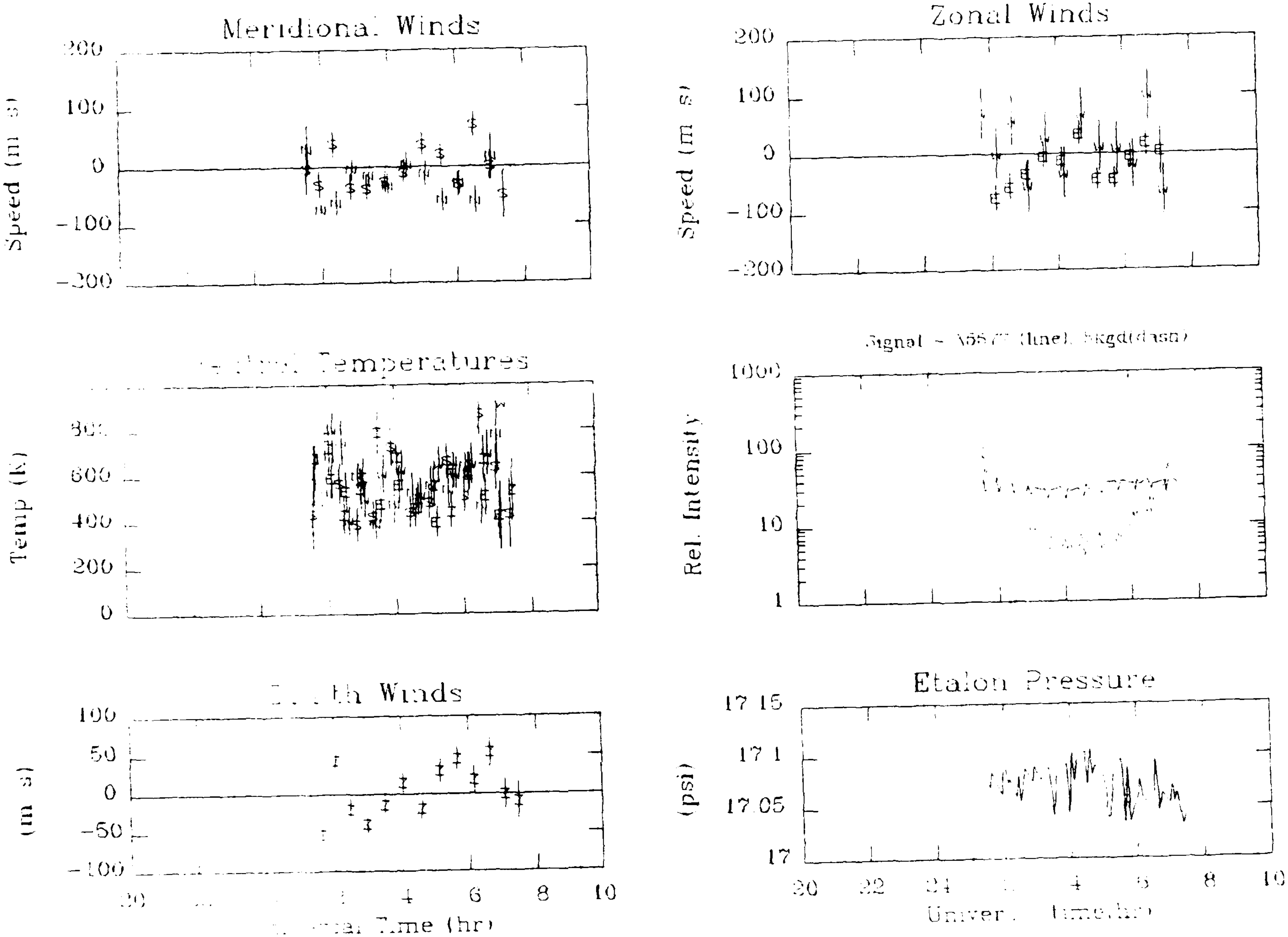
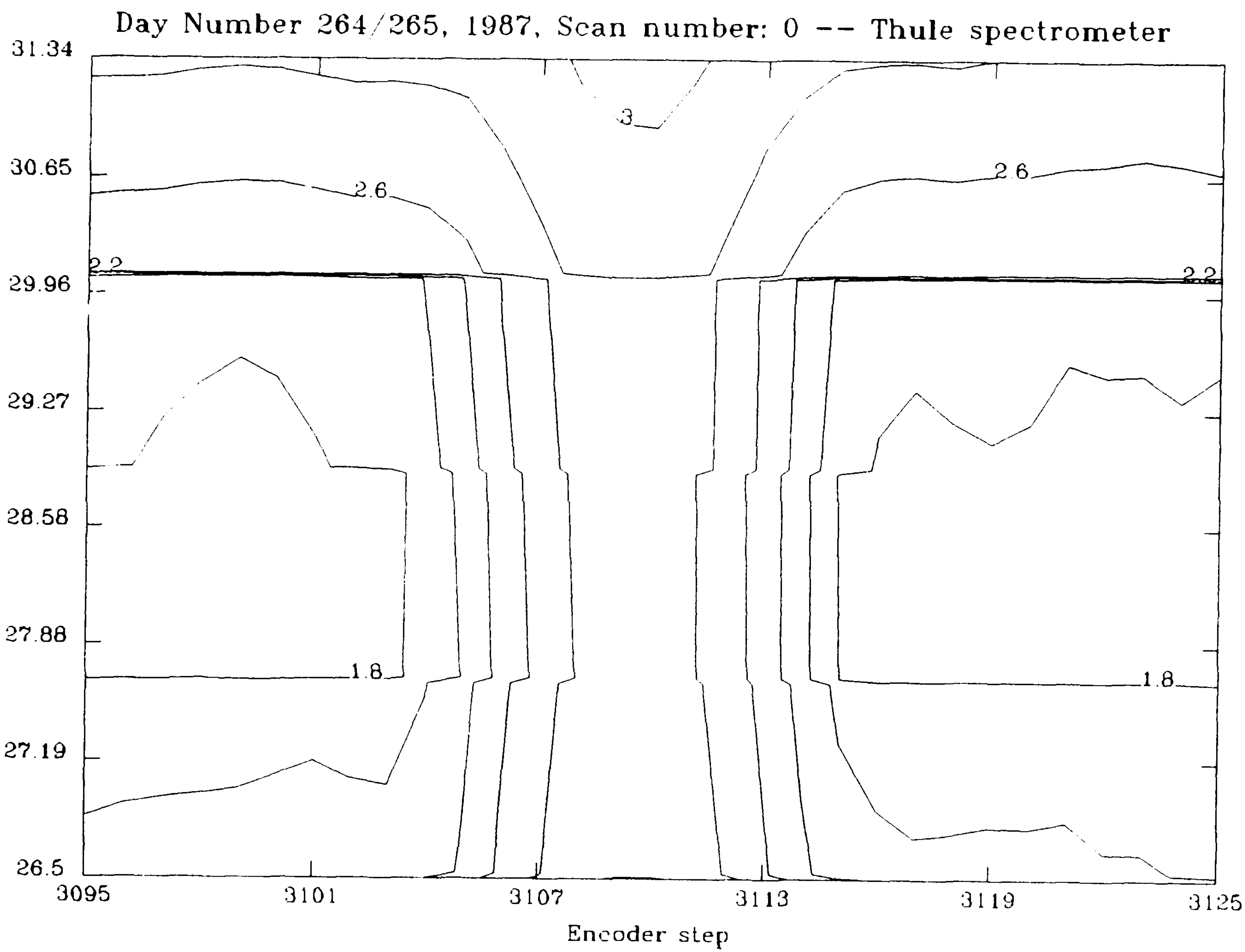


Fig. 5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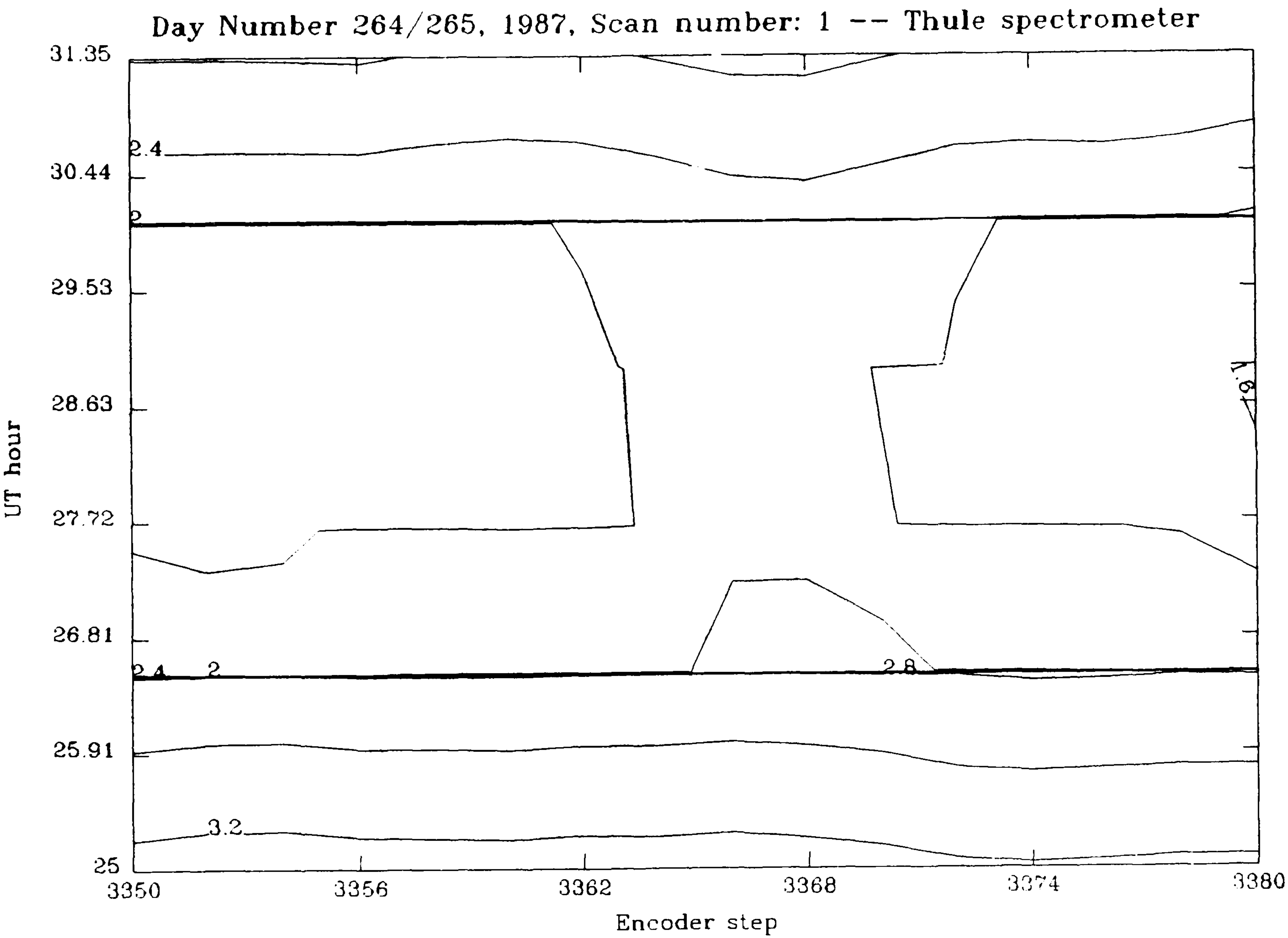
30.65
29.96
29.27
28.58
27.88
27.19
26.5
UT hour
3095
3101
3107
3113
3119
3125
Encoder step
3
2.6
2.2
1.8

Fig. 6a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UT hour
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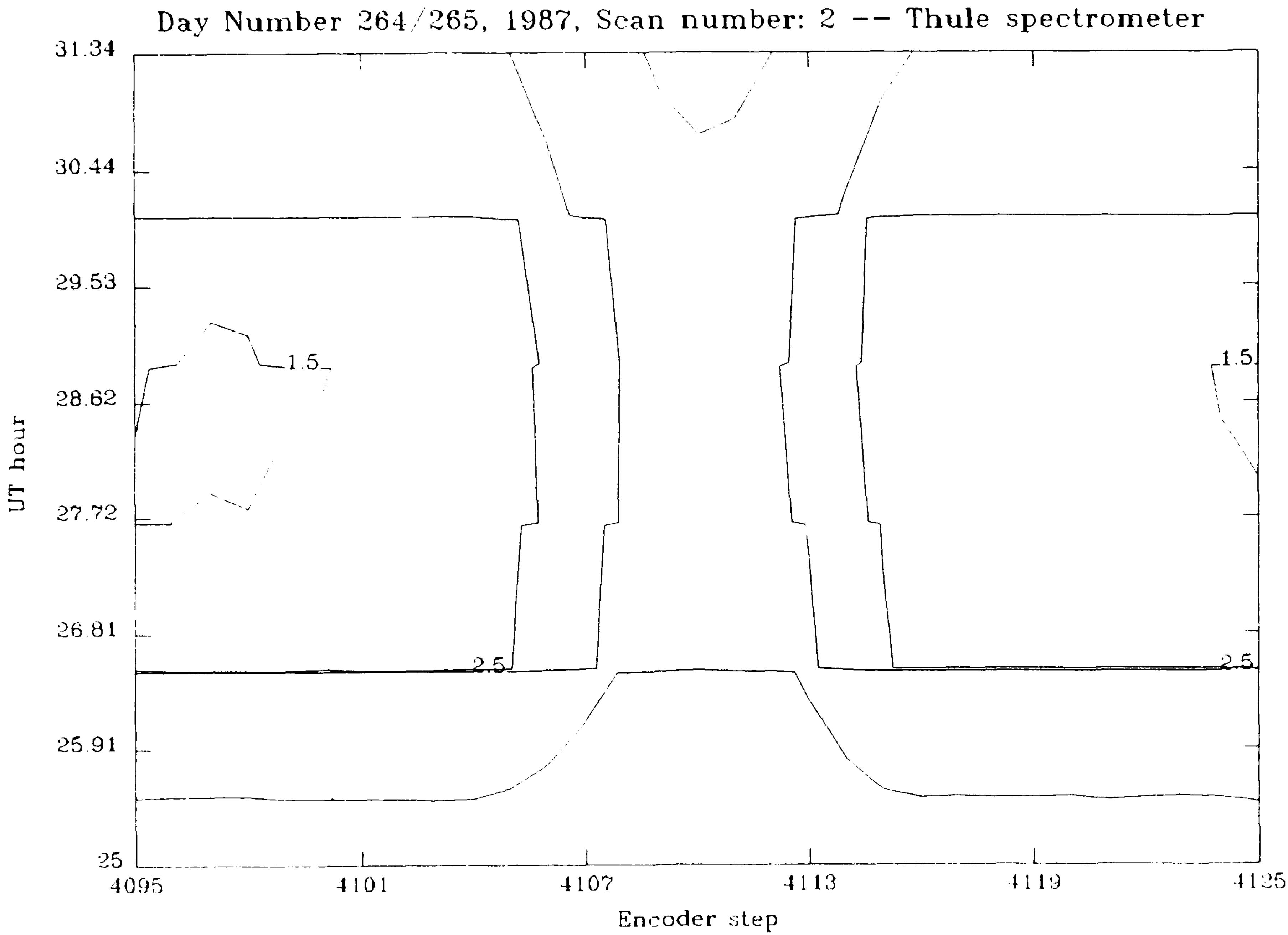
30.44
29.53
28.63
27.72
26.81
25.91
25
3350
3356
3362
3368
3374
3380
Encoder step
2.4
2
1.6
2.8
3.2

Fig. 6b



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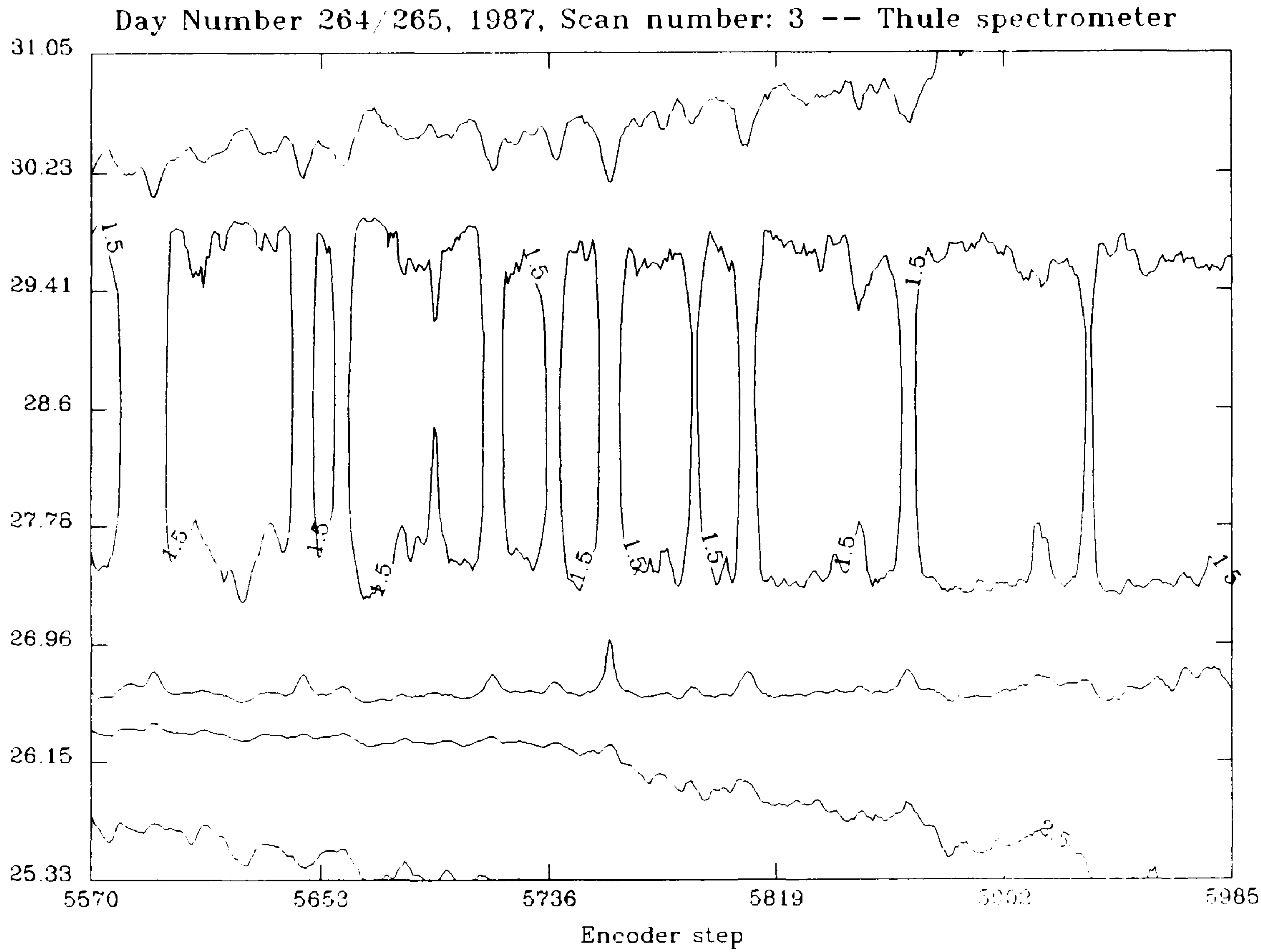
4113
4119
4125
Encoder step

Fig. 6c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28.6
27.76
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26.15
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5819
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Encoder step
1.5
2.5

Fig. 6d

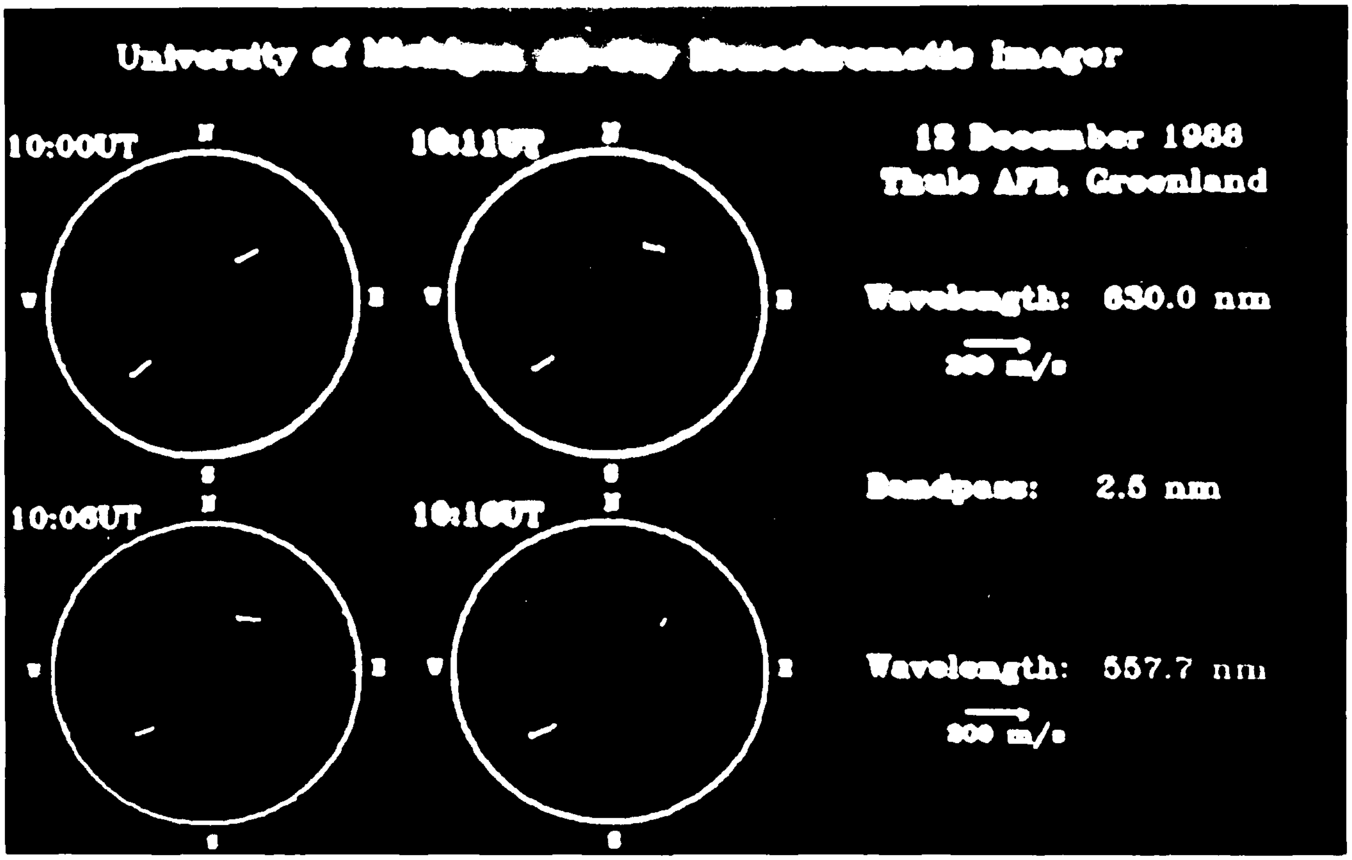
University of Michigan All-Sky Monochromatic Imager
10:00UT
10:11UT
10:06UT
10:16UT
12 December 1988
Thule AFB, Greenland
Wavelength: 630.0 nm
Bandpass: 2.5 nm
Wavelength: 557.7 nm

Fig. 7a

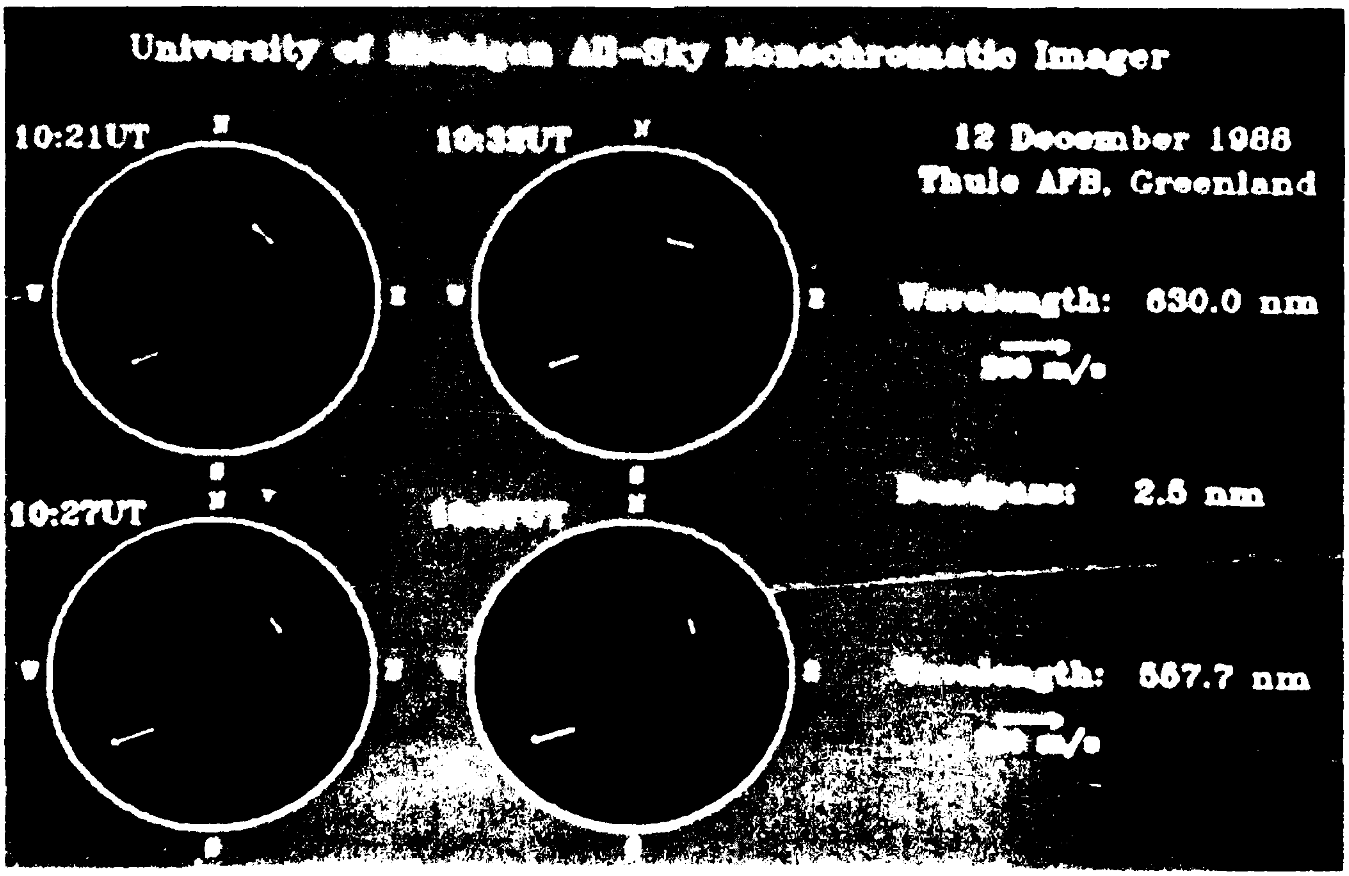
University of Michigan All-Sky Monochromatic Imager
10:21UT
10:32UT
10:27UT
12 December 1988
Thule AFB, Greenland
Wavelength: 630.0 nm
Bandpass: 2.5 nm
Wavelength: 557.7 nm

Fig. 7b

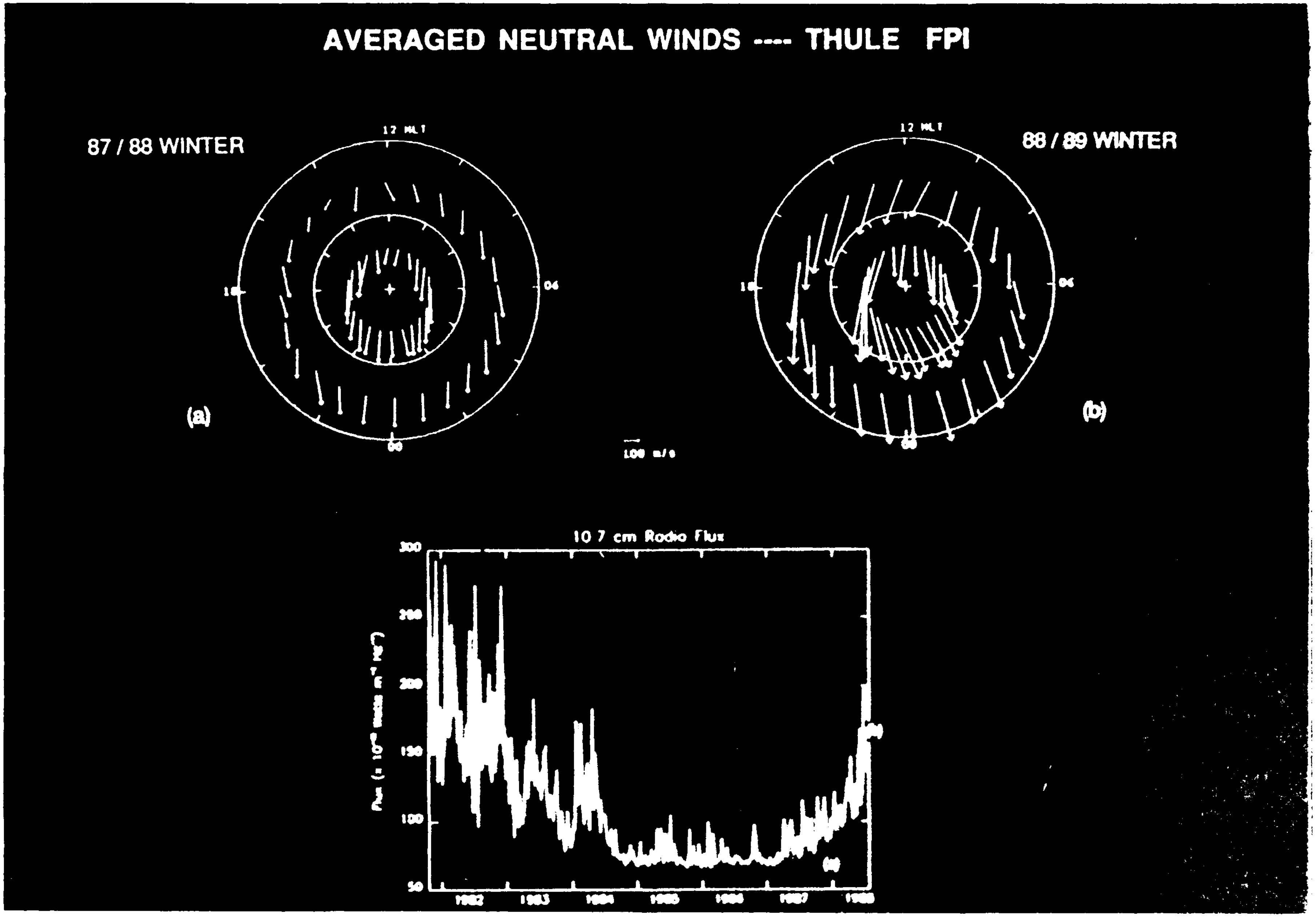
AVERAGED NEUTRAL WINDS ---- THULE FPI
87 / 88 WINTER
88 / 89 WINTER
12 MLT
18
06
00
(a)
(b)
100 m/s
10.7 cm Radio Flux
300
250
200
150
100
50
1982
1983
1984
1985
1986
1987
1988

Fig. 8

APPENDIX A

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Polar Cap Diurnal Temperature Variations: Observations and Modeling

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A diurnal variation in thermospheric temperature in the geomagnetic polar cap at solar minimum (January 1987) has been observed using high spectral resolution measurements of the O(^1D) emission line made with the Fabry-Perot interferometer located at Thule, Greenland (76°32'N, 68°45'W, Λ = 86). The temperature maximum in the diurnal cycle occurs at 1600 UT, which is very near the magnetic local noon period in the northern hemisphere. Data from the wind and temperature spectrometer on the Dynamics Explorer 2 satellite show a similar diurnal variation in the northern polar cap thermospheric temperature for near solar maximum conditions. In an attempt to find the mechanisms responsible for the variation, we have used the diagnostics package developed for use with the NCAR thermospheric general circulation model (TGCM), which allows the tracking of individual parcels of gas in both time and space by interpolation through the model grid. At each of the predicted loci of the parcels we have examined the physical factors which influence the thermal balance by decomposing the thermodynamic equation into its constituent terms. By tracing the trajectory of a parcel backward in time and space from the location of Thule (i.e., well inside the geomagnetic polar cap), we have been able to show, for a model run with input parameters pertaining to day 314, 1976 (i.e., several weeks from solstice near solar minimum), that the observed diurnal temperature variation is attributable to the following factors: (1) the degree of solar heat input that a parcel experiences en route to the polar cap, which is dependent on whether or not it crosses the solar terminator, (2) the route a parcel takes through the polar cusp, i.e., whether the parcel skirts the edge or passes directly through the center determines the total quantity of heat added by soft particle impact within the cusp, (3) the time duration between maximum heat input from the combination of solar, cusp, auroral and Joule sources and the time of arrival overhead at Thule. In addition, we have shown (1) that the hot geomagnetic polar cap reported by Hays et al. (1984) is primarily due to transport of heat into the polar cap by parcels that were heated by auroral, Joule and cusp sources, and (2) that the hydrodynamical variations in the winter high-latitude regions from solar maximum to solar minimum are insufficient to mask the thermodynamical effects related to the offset of the geographic and geomagnetic poles.

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Thermospheric Winds in the Geomagnetic Polar Cap For Solar Minimum Conditions

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A Fabry-Perot interferometer located at Thule, Greenland (Λ=86) has monitored the *F* region thermospheric neutral wind over the northern hemisphere geomagnetic polar cap during the 1985/1986 solar minimum, winter solstice period. The wind observations were obtained by determining the Doppler shift of the (O I) 15,867-K (630.0-nm) emission. We present a subset of the measurements made during December 1985 to January 1986. Three factors make this data set unique and particularly valuable for a study of the effects of the deposition of energy and momentum from the magnetosphere into the high-latitude neutral thermosphere. These factors are (1) the proximity of the observing station to the geomagnetic pole, (2) the continuous nature of the coverage due to the high geographic latitude and polar night conditions, and (3) the fact that the data set was obtained near solar minimum. The measured winds are compared with the simulations of the NCAR thermospheric general circulation model (TGCM). The results show that winds in the geomagnetic polar cap have a fundamental diurnal character, in accord with model predictions, with typical speeds of ~200 m/s, generally in an antisunward direction. A large degree of variability, however, in both the magnitude and direction of the winds is observed, including evidence for curvature in the neutral flow within the instrumental region of observation (~400 km diameter). Acceleration of the meridional component across Thule is observed at times. This acceleration is ascribed to regions of ion-drag forcing associated with the magnetospheric input of energy and momentum. Characteristic asymmetric wind signatures were seen that were well correlated with positive or negative changes in the B_y component of the interplanetary magnetic field.

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Collaborative Studies of Polar Cap Ionospheric Dynamics

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An important parameter in the modelling of polar cap ionospheric phenomena relating to scintillations and small scale irregularities is the thermospheric wind. The magnitude and direction of the flow of the neutral atmosphere determines how quickly these features of the polar cap morphology develop and grow. The AFGL contract (DoD-C-F19628-83-K-0035) was awarded to the University of Michigan to support the construction and installation of an automatic instrument designed to observe automatically thermospheric winds and temperatures at Thule Air Base in Greenland. The Space Physics Research Laboratory carried out this task and operated the observatory successfully throughout the 1985/1986 winter between early December 1985 and 1 April 1986. This report presents a description of the instrumentation and a set of plots showing the reduced set of observations of the clear nights in this period.

APPENDIX B

ABSTRACTS:

Thermospheric Temperature Measurements in the Geomagnetic Polar Cap for Winter Solstice, Solar Minimum Conditions

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Measurements of thermospheric winds and temperatures in the geomagnetic polar cap have been obtained by the Fabry-Perot Interferometer at Thule, Greenland (76° 32' N, 68° 45' W), during the 1986/1987 solar minimum, winter solstice period. The temperature measurements show a diurnal variation from ~800°K to ~900°K with maxima at ~1000 local time (LT) and ~1900 LT. We have compared the measurements with the predictions of the NCAR Thermospheric General Circulation Model (TGCM) and performed a decomposition of the terms in the model to assess the relative importance of each in producing the observed diurnal variations.

PRESENTED AT: The American Geophysical Union, 1987 Spring Meeting, Baltimore, MD

DATE: May 18 - 21, 1987

Thermospheric Neutral Wind at High Latitude

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Recent experimental studies of thermospheric wind structure at high latitude from satellite and ground-based techniques have illustrated the large dynamic range of the observed phenomena. At solar maximum the Dynamics Explorer satellite regularly observed wind speeds in excess of 600m/sec in the polar thermosphere. These results have been compared extensively with theoretical models, such as the NCAR Thermosphere General Circulation Model. Recent ground-based measurements in the Northern Hemisphere polar cap using the Fabry-Perot Interferometer at Thule Air Base, however, have shown that, for the current solar minimum conditions, the polar wind speeds are much reduced from those observed by the earlier satellite mission. The present experimental and theoretical status of an understanding of the high latitude thermospheric wind systems will be reviewed in this contribution. The prospects for attaining a predictive capability for the winds sytems will also be discussed, based on approaches using both numerical and semi-empirical modeling.

PRESENTED AT: The AAS/AIAA Astrodynamics Conference in Kalispell, MT

DATE: August 10 - 13, 1987

Monochromatic Images of Aurora from Thule,Greenland Obtained with a Non-intensified Charged-Coupled Device All-Sky Camera

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A monochromatic all-sky imager, that utilises a non-intensified Charged-Coupled Device (CCD) array as a detector, has been built at the Space Physics Research Laboratory, Ann Arbor. The CCD is a standard Fairchild line transfer device (CAM 5000) that has a thermoelectric cooling pad built under the chip. However, the rate of generation of thermal electrons on the chip is too high when only the manufacturers peltier cooler is used (i.e. this reduces the CCD to 20°C below ambient). We therefore placed the entire assembly inside a Products for Research, two stage thermoelectric cooler that could bring the CCD to 60°C below ambient. This proved sufficient for integration times up to 10 minutes before thermal noise became a problem. The instrument was taken to Thule, Greenland where all-sky images of the aurora in the polar cap, at wavelengths of 630nm and 557.7nm, were recorded automatically every 5 minutes during December, 1988 and January 1989. We will describe the instrument and show some image sequences taken with it.

PRESENTED AT: The American Geophysical Union, 1989 Spring Meeting, Baltimore, MD

DATE: May 7 - 12, 1989

Polar Cap Thermosphere Dynamics: Observations from Ground and Space

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Measurements of thermospheric winds and temperatures within the polar cap were made during the 1981-1983 period using instrumentation on the NASA Dynamics Explorer-2 spacecraft. In addition to the satellite measurements, ground-based observations using a Fabry-Perot interferometer sited at Thule Air Base in Northern Greenland have been made from 1984 up to the present. In this contribution we summarize the measurements made in these two programs. The observations are used to quantify the mean neutral wind pattern for various geophysical circumstances and to investigate departures from the mean induced by storm-time disturbances.

PRESENTED AT: The International Association of Geomagnetism & Aeronomy, 6th Scientific Assembly, Exeter University, United Kingdom

DATE: July 24 - August 4, 1989

Ground Based OI (6300 Å) Fabry Perot Interferometer Observations from Thule and Søndre Strømfjord, Greenland: Systematics in the F Region Neutral Winds Observed Concurrently by Both Instruments

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Measurements of polar upper atmosphere OI (6300Å) emissions by Fabry Perot interferometers at both Thule and Søndre Strømfjord, Greenland, have been acquired since 1986. Previously, studies of the systematics of F region neutral winds have been performed using only a single station [eg. Niciejewski et al, EOS, 1989]. The two stations are separated by ~900 km, and thus during clear sky conditions, both Fabry Perot interferometers can simultaneously observe a large portion of the polar cap F region. In this presentation, we will discuss results from two modes of operation: 1) concurrent observations of the same volume from both stations obtained during the 1987/88 observing season, and 2) independent meridional and zonal neutral wind observations obtained at the same time from both stations. The latter will be compared with VSH model predictions of the neutral winds for a case of low geomagnetic activity.

PRESENTED AT: The American Geophysical Union, 1990 Spring Meeting, Baltimore, MD

DATE: May 29 - June 1, 1990

Ground-Based Observations of Ion/Neutral Coupling at Thule and Qânâq, Greenland: IMF B_Z Dependence

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During December, 1988, twenty-four hours of darkness and clear sky conditions permitted continuous observations of the OI(6300Å) airglow by a Fabry-Perot interferometer located at Thule, Greenland. Thus, a long term continuous record of the F-region neutral winds was obtained for that month. During this same time period, a digital ionosonde located at Qânâq, Greenland (110 km due north of Thule) was in operation measuring electron density profiles and F-region ion drifts. Using these diagnostics, a one to one correspondence between the F-region neutral wind and the ion drift measurements may be established. This allows for the investigation of ion / neutral coupling from the ground-based observations at a temporal resolution of about 15 minutes. From the 16th to the 24th of December, IMF data from the IMP 8 satellite were available and indicated intervals of B_Z northward IMF conditions during this period. Signatures of sunward directed neutral winds and ion drifts were observed coincident with northward IMF. The response of the neutral winds to sunward ion drifts under B_Z northward conditions is investigated.

PRESENTED AT: The American Geophysical Union, 1990 Spring Meeting, Baltimore, MD

DATE: May 29 - June 1, 1990

An Investigation of a Polar Cap Arc Sequence Using Ground-Based Measurements at Thule, Greenland

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An investigation of a series of polar cap arcs will be presented. Data obtained on 12 December 1988 during a High Latitude Plasma Structure (HLPS) campaign will be used to discuss the structure and dynamic behavior of the upper atmosphere during this occurrence. A series of OI (6300Å) and OI (5577Å) all-sky images and Fabry-Perot interferometer measurements were acquired at the University of Michigan airglow facility in Thule, Greenland (L=86°) on December 12, 1988 from 0851 UT to 1120 UT. The all-sky images depict intense sun-aligned arcs later followed by several diffuse, horseshoe-shaped arcs. Simultaneous FPI data obtained for both OI emissions show elevated temperatures, and initially, strong anti-sunward winds. Additional data has been obtained through digisonde measurements in the form of electron densities and ion drifts, and irregularity drift measurements using the spaced receiver scintillation technique. These data will be used along with the optical signature of the arcs to describe the morphology and dynamics at altitudes of 110 kilometers using the OI (5577Å) emission and 220 kilometers using the OI (6300Å) emission.

PRESENTED AT: The American Geophysical Union, 1990 Spring Meeting, Baltimore, MD

DATE: May 29 - June 1, 1990

The Behaviour of the High-Latitude F-Region Neutral Thermosphere in Relation to IMF Parameters

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Ground based incoherent scatter radar and Fabry Perot interferometer studies in the northern high latitudes during the period 1983 to 1989 have shown that the F-region neutral wind field pattern depends upon the sign of the IMF parameters. For example, the cell structure of the northern hemisphere high latitude neutral wind field during periods of low geomagnetic activity depends to a large degree upon the sign of the IMF B_y parameter. Long term monitoring of the F-region thermosphere by FPI in Thule, Greenland, and by both FPI and ISR in Søndre Strømfjord, Greenland, have made it possible to produce maps of average meridional and zonal wind fields for various IMF configurations for northern high latitudes. Comparison of observations with theoretical wind field modelling, such as the Vector Spherical Harmonic model, indicates that most observed features are within the context of the models.

PRESENTED AT: COSPAR 1990 Plenary Meeting, The Hague, Netherlands

DATE: June 25 - July 6, 1990